ROUTE OPTIMIZATION STUDY

RURAL & URBAN DISTRIBUTION SYSTEMS

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MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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1. EXECUTIVE SUMMARY

One of the most expedient methods to save transportation dollars is to conduct a route optimization analysis. Simply stated, route optimization is a process of tailoring a company's route system to result in the most cost effective way of meeting their transportation needs.

One specific benefit of route optimization is that of energy savings through reduced fuel consumption. The study outlined in this report was undertaken to demonstrate the potential energy savings of route optimization. The study was conducted in two phases; rural distribution system and urban distribution system.

The system studied consisted of 10 routes collecting milk from 77 producers and the delivery of it to the processing plant. Four trucks handled the routes.

By applying route optimization techniques the following changes and corresponding savings were identified:

1) The removal of one route and reallocation of customers to be serviced from a different base, would result in a daily reduction of 100 km due to the change in plant location, and 108 km in additional travel for the operator. This would amount to a total savings of approximately 3,120 km monthly or 1,485 litres of fuel.

2) Assigning routes to minimize the distance travelled from the carrier's home base to the pick-up points resulted in a monthly reduction of 2,265 km, approximately 1,080 litres of fuel.

3) Route optimization using the existing truck fleet resulted in a reduction of 7,230 km monthly and a reduction in fuel consumption of 3,675 litres.

4) Route optimization using a fleet of high-capacity trucks resulted in a reduction of 8,190 km/mos. and 4,063 litres of fuel.

5) Extrapolation of the analysis on the existing fleet indicates that on a province-wide basis reduction in fuel consumption of 497,000 litres annually could be achieved due to route optimization.

URBAN ROUTE OPTIMIZATION:

A major distributor in Winnipeg with warehouse/distribution facilities servicing a number of customers throughout Western Canada agreed to participate in this study. Customers range in size and type from large bulk customers to small retail accounts.

The key objective of the study was to determine an optimum routing system for deliveries within an urban area which would result in a significant decrease in total fleet travel distance.

The following conclusions and recommendations were made:

1. Daily travel distance reductions in the order of 25% and fuel consumption reductions of approximately 22,250 litres per year would result from the application of route optimization techniques.

2. The client's operating costs, due to the need for fewer trucks, would be reduced from $130,000 to $180,000.

3. The existing delivery zone system should be strengthened and zone boundaries established on the basis of current customer demand. Six zones covering the city are suggested on the basis of this analysis.

4. Order cut-off times should be established as follows:

   Period 1: 7:00 a.m. to 11:00 a.m. - same day delivery

   Period 2: 11:00 am to 3:00 p.m. - same day delivery with freight charge

   Period 3: 3:00 p.m. to 9:00 p.m. - next day delivery

5. A minimum order size should be established and that orders less than minimum should be subject to a freight-added charge.

6. Customer pre-planning of orders should be encouraged.

7. Consideration should be given to the installation on the loading dock of an on-line computer terminal, linked to the company's main computer, to enable the foreman to build truck loads more quickly and accurately.

1. SOMMAIRE

Entre toutes les formules qui permettent de réduire les coûts du transport, les techniques d'optimisation des itinéraires sont parmi les moins onéreuses à mettre en oeuvre. En termes simples, ces techniques consistent à modifier le tracé des itinéraires empruntés par les véhicules d'une compagnie de façon à rentabiliser au maximum les opérations de transport de cette dernière.

Un des avantages immédiats qu'apporte l'optimisation des itinéraires est la diminution sensible des coûts grâce à la réduction de la consommation de carburant. L'étude dont il est question dans le présent rapport a été entreprise dans le but de faire ressortir l'importance éventuelle des économies réalisables sur le plan de l'énergie grâce à un réseau d'itinéraires optimisé. Cette étude s'est faite en deux volets, dont l'un porte sur les réseaux de distribution ruraux et l'autre sur les réseaux de distribution urbains.

Le réseau que nous avons analysé était constitué de dix itinéraires, empruntés pour le ramassage du lait auprès de 77 producteurs et la livraison à l'usine de traitement. La desserte était assurée par quatre camions.

Appliquées à ce réseau, les techniques d'optimisation des itinéraires se traduiraient par les avantages suivants:

1) La suppression d'un itinéraire et la répartition des clients entre les neuf itinéraires restants se traduiraient par un raccourcissement de 100 km des parcours quotidiens du fait que ces clients seraient desservis à partir de terminus différents, ainsi que par une diminution de 108 km sur le parcours de l'exploitant. Ce changement représenterait une réduction mensuelle de 3 120 km, soit une économie de 1 485 litres de carburant.

2) Le choix de nouveaux itinéraires visant à minimiser la distance parcourue entre le terminus du transporteur et les points de

ramassage a permis de diminuer de 2 265 km la distance à parcourir, ce qui représente une économie de 1 080 litres de carburant.

3) L'optimisation des itinéraires empruntés par le parc de camions actuel a permis de diminuer de 7 230 km la distance mensuelle parcourue et de réduire de 3 675 litres la consommation de carburant.

4) Si le parc était composé de camions à forte capacité de charge, l'optimisation des itinéraires se traduirait par une réduction mensuelle de 8 190 km, soit une économie de 4 063 litres de carburant.

5) À partir des données de l'analyse sur le parc actuel de camions, on peut supposer que l'optimisation des itinéraires déboucherait, à l'échelle de la province, sur une économie annuelle de 497 000 litres de carburant.

OPTIMISATION DES ITINÉRAIRES URBAINS:

Un important grossiste de Winnipeg a bien voulu participer à la présente étude. Ce grossiste dispose d'installations d'entreposage et de distribution et il dessert de nombreux clients dans l'Ouest du Canada. La clientèle est très diversifiée, allant des entreprises de gros aux petits détaillants.

L'étude avait pour principal objectif de définir un réseau d'itinéraires optimal au sein de la zone urbaine afin de réduire sensiblement la distance parcourue par les camions du parc.

Les conclusions et recommandations étaient les suivantes:

1. Il serait possible, en appliquant les techniques d'optimisation des itinéraires, de diminuer d'environ 25 p. 100 la distance parcourue annuellement et de réduire d'environ 22 250 litres la consommation annuelle de carburant.

2. Du fait qu'il serait possible d'assurer le même service avec un nombre moindre de camions, les clients seraient en mesure de réaliser des économies de l'ordre de 130 000 à 180 000 $ sur leurs frais d'exploitation.

3. Il y aurait lieu de consolider le système actuel des zones de livraison, et d'établir les limites de ces zones en fonction de la demande actuelle. En fonction des résultats de l'analyse, nous recommandons que la ville soit découpée en six zones.

4. Les heures limites d'inclusion des commandes devraient être les suivantes:

   Période 1: 7h à 11h - livraison le même jour.

   Période 2: 11h à 15h - livraison le même jour moyennant les frais de transport.

   Période 3: 15h à 21h - livraison le lendemain.

5. Il faudrait établir un seuil minimum pour les commandes en-dessous duquel les clients devraient s'acquitter d'une partie des frais de transport.

6. Il y aurait lieu d'encourager chez les clients la pré-planification des commandes.

7. Il y aurait lieu d'envisager l'installation, sur l'aire de chargement, d'un terminal relié à l'ordinateur principal de la compagnie. Ce terminal permettrait au contremaître de planifier plus rapidement et de façon plus efficace le chargement des camions.

RURAL DISTRIBUTION SYSTEM

1. INTRODUCTION

The Route optimization demonstration project described in this report was initiated under the Canada-Manitoba Conservation and Renewable Energy Demonstration Program. The intent of the project was to demonstrate the potential energy savings to be gained by route optimization techniques applied to rural distribution operations, urban distribution operations and a school bus system. This report deals with the rural system.

The project was administered by the Transportation Programs Branch of the Manitoba Department of Highways and Transportation on behalf of the Manitoba Department of Energy and Mines and the federal Department of Energy, Mines and Resources. Damas and Smith, a Division of DSL Consultants Ltd. were retained in August, 1982 to carry out the project.

Selection of a rural distribution system was undertaken by the Transportation Programs Branch with input from the consultants. Agreement was reached with the Manitoba Milk Producers' Marketing Board in September, 1982, to study a route system in Southwestern Manitoba.

The Milk Marketing Board operates a system of rural collection routes to collect and transport milk in bulk from the producers to 19 milk processing plants throughout the province. The Marketing Board currently has contracts with 27 carriers who operate a total of 64 trucks serving 1,239 producers. The contracts are each for one year with an automatic renewal. Haul rates are based on a formula which recognizes fixed costs and variable operating costs.

Typically, milk is collected from each producer every second day. Each daily run collects from 6 to 12 producers, depending on the individual producer's output and the truck capacity.

For the purpose of this study, the Milk Marketing Board selected an operation which is representative of the "average" operation. Route data and copies of waybills for the most recent June and December operating months were made available by the Marketing Board. These two months are normally the highest and lowest in terms of production volume.

The objective of the study was to examine the existing route systems and to determine potential savings in distance travelled and fuel consumed by optimizing the route system. During the study it became apparent that further reductions could be achieved by considering truck capacity and the geographic relationship of the carrier's home base to the route system.

2. DEFINING THE CURRENT SYSTEM

The collection system for the plant at Location A was examined. The existing system involes two independently owned trucking operations. One, consists of two trucks each of 7,594 litre rated capacity.* The other also consists of two trucks, one with a 13,290 litre rated capacity, the other with 11,392 litre rated capacity. The first operation is based in Location A while the other two trucks are based in Location B.

The current method of collection is by 10 established routes covering a total of 2,272 km. This distance is covered every two days, producing a monthly total of 2,272 x 15 = 34,080 km. The route system is shown in Figures 1A & 1B and tabulated in Appendix A (excluding Route F). Existing routes are noted alphabetically, with collection points within the route noted numerically (A1, C2, B3, etc.). Routes B and C are covered by the same truck in a single day as are Routes I and K. Routes A to E are served by the two trucks based in Location A while routes F to K are served by the two trucks based in Location B.

* Actual capacity can be as much as 3 percent over rated capacity.

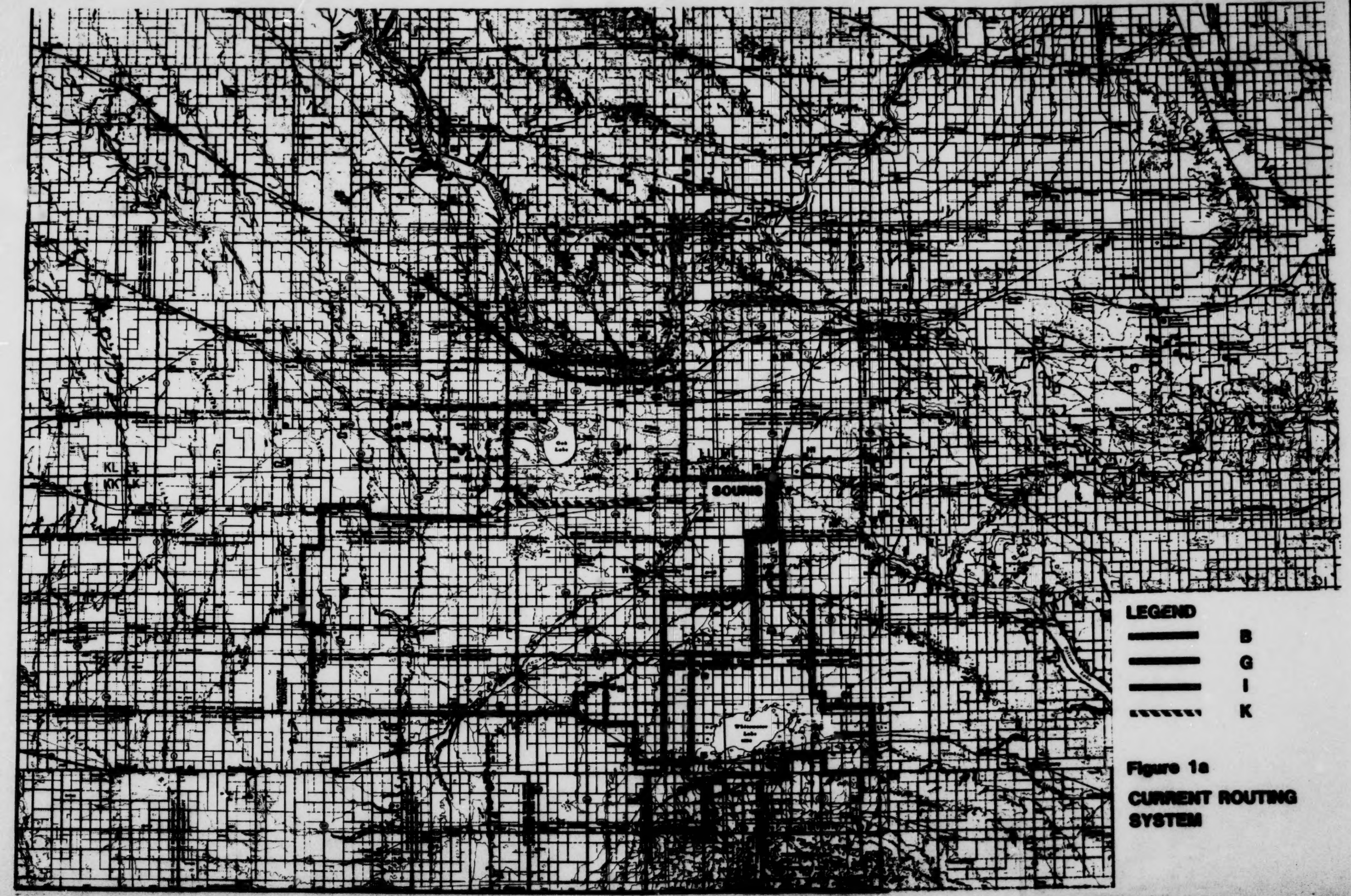

Figure 1a

CURRENT ROUTING SYSTEM

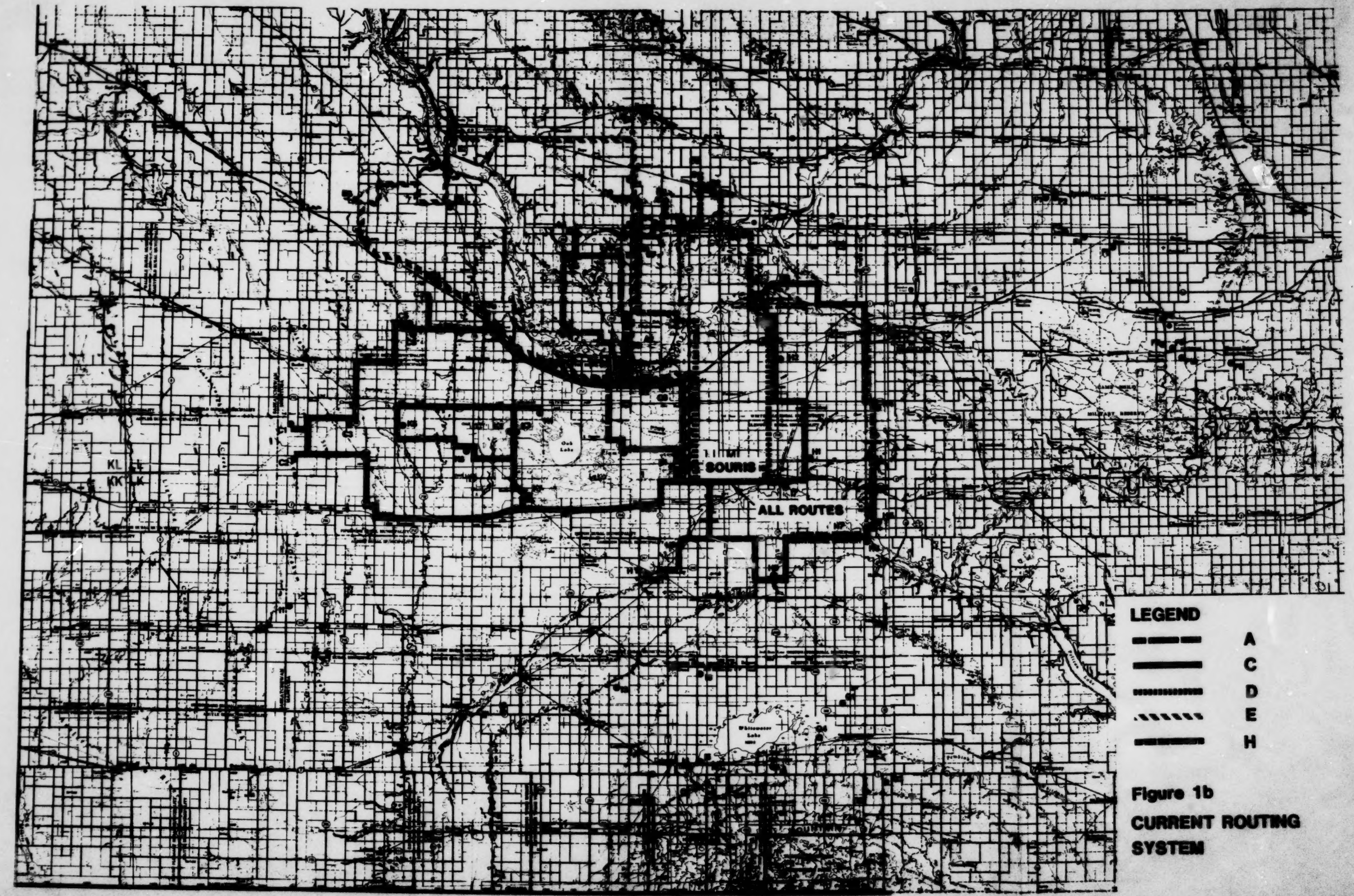

Figure 1b
CURRENT ROUTING SYSTEM

Before analyzing the current route system serving the plant in Location A, consideration was given to the obvious inefficiencies caused by overlapping service areas. The route designated on Figures 1A & 1B as Route F lies entirely to the east of Brandon, where two liquid milk plants are located. Thus the Milk Marketing Board is incurring substantial additional costs in hauling milk the additional distance to Souris and by-passing two plants en route.

We recognize that historical relationships between haulers and producers have played a signficant part in establishing current route systems. The preservation of these relationships is a policy matter which cannot be dealt with in this study. Nonetheless, since the objective of this study is to identify methods of reducing energy consumption and costs, the inefficiency of overlapping service areas must be identified.

In this case, the cost saving achieved by diverting Route F to Brandon would be the incremental operating cost at $0.175/km for the return distance between the Location A and Brandon plants. Assuming this to be 100 km, the daily saving would be $17.50 and the monthly saving $262.50. In terms of energy savings, since Route F is serviced by a Location B-based truck, an additional cost to the operator is incurred in covering the return distance between Location B and Location A. This cost is not reimbursed directly by the Milk Marketing Board. However, assuming the same cost/km figure ($0.175) and a round trip distance between Location B and Location B of 108 km, a further monthly cost saving of $283.50 can be identified.

The inclusion of Route F in the analysis of the system serving the Location A plant would tend to distort the analysis. It is assumed, therefore, that a route rationalization can be made to remove Route F from the Location A system and replace it with a similar sized route contiguous to the existing Location A service area.

The analysis is thus based on the remaining 9 routes serving the Location A plant. The nine routes under study cover a total distance of 29,400 km per month. Since the objective of the demonstration program is to identify relative energy and cost savings, the elimination of Route F will not change the findings and conclusions of the study and will, as noted above, remove a distortion caused by overlapping rather than lack of route optimization.

3. CRITERIA FOR OPTIMIZATION

When examining any distribution system there are two primary factors which are of the greatest concern. They are, first, the capacity of the vehicles under study, and secondly, the total distance travelled. The objective is to maximize the load per truck and minimize the distance travelled.

For the purposes of this study, it has been assumed that capacity is limited by seasonal load limits. In Manitoba, the maximum gross vehicle weight (GVW) for 3-axle straight trucks (typical of the bulk milk carriers) is 20,000 kg. A truck with a tank capacity of 11,392 litres can operate within this limit. Since such a truck is operated by one the carriers serving the plant in Location A, this capacity has been chosen as a model.

The analysis was carried out in two ways. Firstly, the operation using the existing 4-truck fleet was analyzed using distance as the only optimization criterion. Secondly, the operation was analyzed using trucks of 11,392 litres tank capacity. A comparison of the two sets of results gives the reductions in operating costs and fuel consumption due to each of the major criteria.

Of the two criteria, distance is the more important. In attempting to minimize distance travelled the following guidelines were used:

A. All routes begin at the truck's home base. While this, in fact, is what happens in practice, payment is made only on an assumed starting point at the plant. Thus there is no incentive to minimize energy consumption by locating the truck operating base close to the collection route.

B. Travel over paved roads is preferable to gravel and more economical (unless excess travel distance is required).

C. Adjacent routes should be planned to provide some degree of back-up such that a truck could be diverted to a pick-up on an adjacent route for reasons of mechanical breakdown, weather or over-capacity.

D. Each route should be capable of completion within normal working hours.

Other criteria used in developing an optimum route system were:

- maximize utilization of geographic groupings of producers;
- minimize distance travelled while loaded;
- minimize uphill routes while loaded.

There are some groupings of producers in this district which obviously should be serviced on the same route. For example, there is a group in the Rural Municipality of Pipestone, another group just north of Turtle Mountain and another north of Griswold. These can be treated, in effect, as small sub-systems.

There is an increased use of fuel and hence a higher cost to the operator when a truck is fully loaded compared with when travelling empty. Thus, greater efficiencies are achieved when the first pick-up is made at a distant point rather than a nearer one. Similarly, uphill routes, such as in the Turtle Mountain area, are covered more efficiently when the truck is empty or only partly loaded.

4. ANALYSIS

The analysis was carried out for the actual volumes shown on waybills for December 1981 and June 1982. June is typically the highest production month while November and December are the lowest. The average daily volume for each producer in each month was calculated and these figures used in the volume-capacity calculations (see Appendix A).

It is recognized that, on some days, this average loading would be exceeded. However, since June is the peak month the likelihood of this occurring in other months is less. Additionally, in the analysis of the optimized routes, care was taken to ensure that no loading exceeded the highest actually recorded. For demonstration purposes, therefore, it was felt that the use of average production figures was appropriate. A later section of the report deals with procedures for back-up in the event of overload or truck break-down situations.

The procedure used to optimize routes was to plot the location of each producer, the carriers' home bases and the plant on a 1:250,000 scale topographical map which showed all Provincial and Rural Municipal roads. A series of overlays was prepared, each with a different route structure.

Total distance travelled and volume were calculated for each route structure and the network refined through successive iterations until distance was minimized and volume maximized (within capacity limits). The option of using a computer program to carry out this task was considered but rejected as being inappropriate for the magnitude of the task involved. (see Appendix B).

All routes began at the home base of the carrier. As noted earlier, this reflects actual practice, although payment is based on the plant location. By recognizing the home base of the carrier and by assigning routes which are geographically closest to the base, significant reductions in travel distance can be realized.

At present, two routes south and east of Location A (Routes G and H, Figure 1A & 1B), are served by trucks based in Location B, 54 km west of Location A. If these two routes were interchanged with Routes A and C the distance travelled by the carriers would be significantly reduced. Under the current method of payment there would be no change in the payments to the carriers but there would be substantial reductions in energy consumption. These reductions are summarized in Table 1.

It should be noted that this interchange of routes can be effected if the capacity of the trucks involved is similar. In fact it is not. As noted earlier, the trucks serving Routes A and C have 7,594 litre rated capacity, while the trucks serving Routes G and H have an 11,392 litre and a 13,290 litre rated capacity respectively.

In addition, Route C is run currently in conjunction with Route B. Nevertheless, the principle of reducing costs by rationalizing routes in relation to home base can be demonstrated.

The first level of route optimization was carried out using the existing fleet structure, ie., 2 trucks based in Location A, each with 7,594 litre rated capacity, and 2 trucks based in Location B, one with 11,392 litre capacity and one with 13,290 litre capacity. Figures 2A & 2B show the optimum route structure developed on this basis. Optimized routes are noted numerically, while the collection points are noted alpha-numerically as in the existing route structure. Table 2 gives the loading histogram for each route for the peak month of June using average daily figures as discussed earlier.

TABLE 1: REDUCTIONS IN ACTUAL TRAVEL DISTANCE AND REVENUE DISTANCE - EXISTING ROUTES RETAINED AND HOME BASES CHANGED

	Existing Distance Travelled (km)		Adjusted Distance Travelled (km)	Reduction in Distance Travelled (km)
	Plant to 1st Pickup	Home Base to 1st Pickup	Base to 1st Pickup	Old Home Base to New Home Base (actual)
A	31	31	31	0
C	92	92	38	(54)
G	48	91	48	(43)
H	10	64	10	(54)
TOTALS	181	278	127	(151)

Note: Even number of routes changed to keep all trucks utilized.

Table 3 gives the reduction in travel distance on a system basis, in actual and percentage terms, as well as estimated fuel saving.

The number of routes is reduced from nine to eight. Routes 1 to 4 are based in Location B while Routes 5 to 8 are based in Location A. In effect, the double routes currently operated by each of the carriers (ie., B and C, I and K) have been eliminated and the route structure optimized. A loading imbalance is created in that Route 8 only utilizes about 50 percent of the truck capacity but this has some advantage in that this truck can operate as a back-up to the other smaller truck based in Location A.

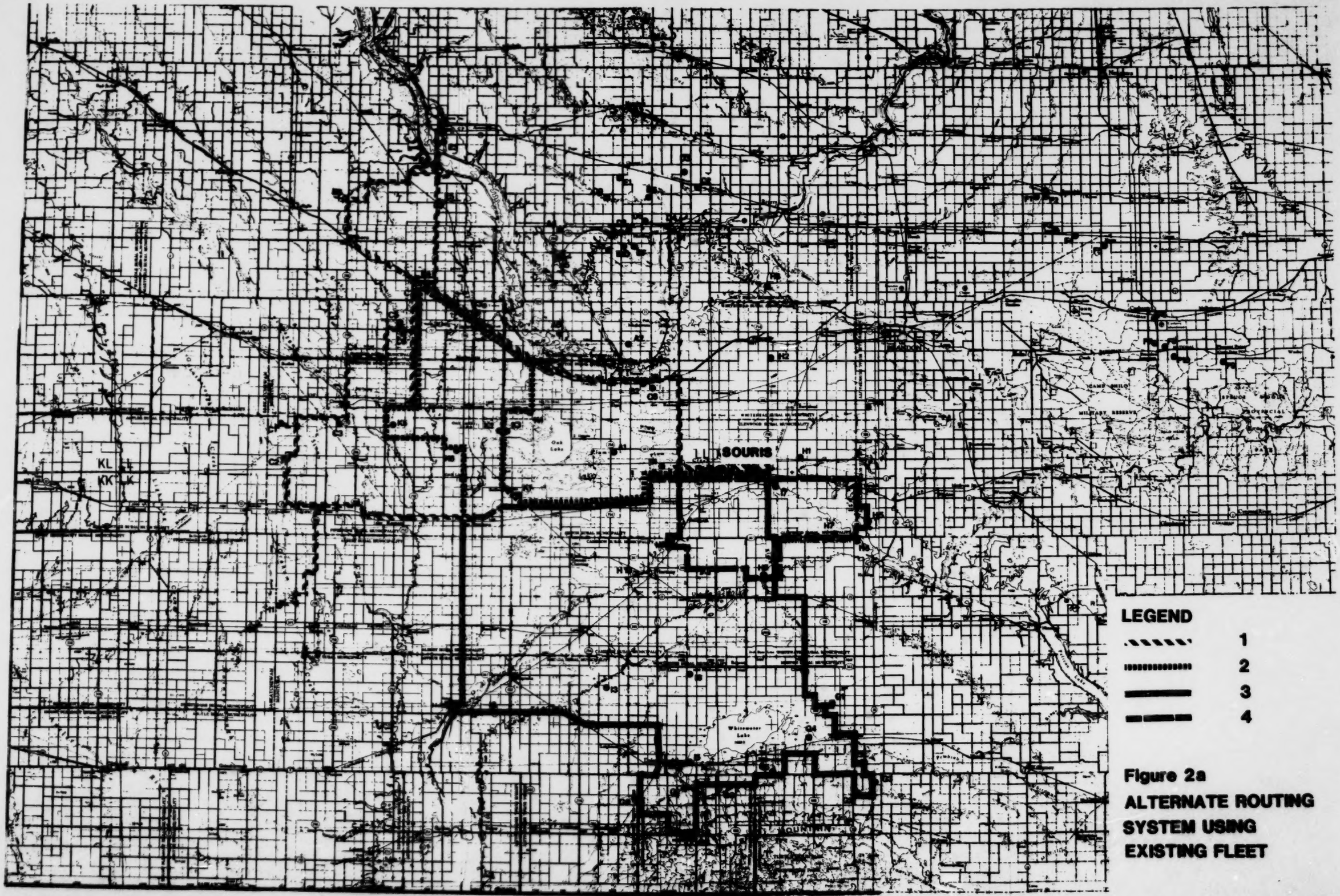

Figure 2a
ALTERNATE ROUTING SYSTEM USING EXISTING FLEET

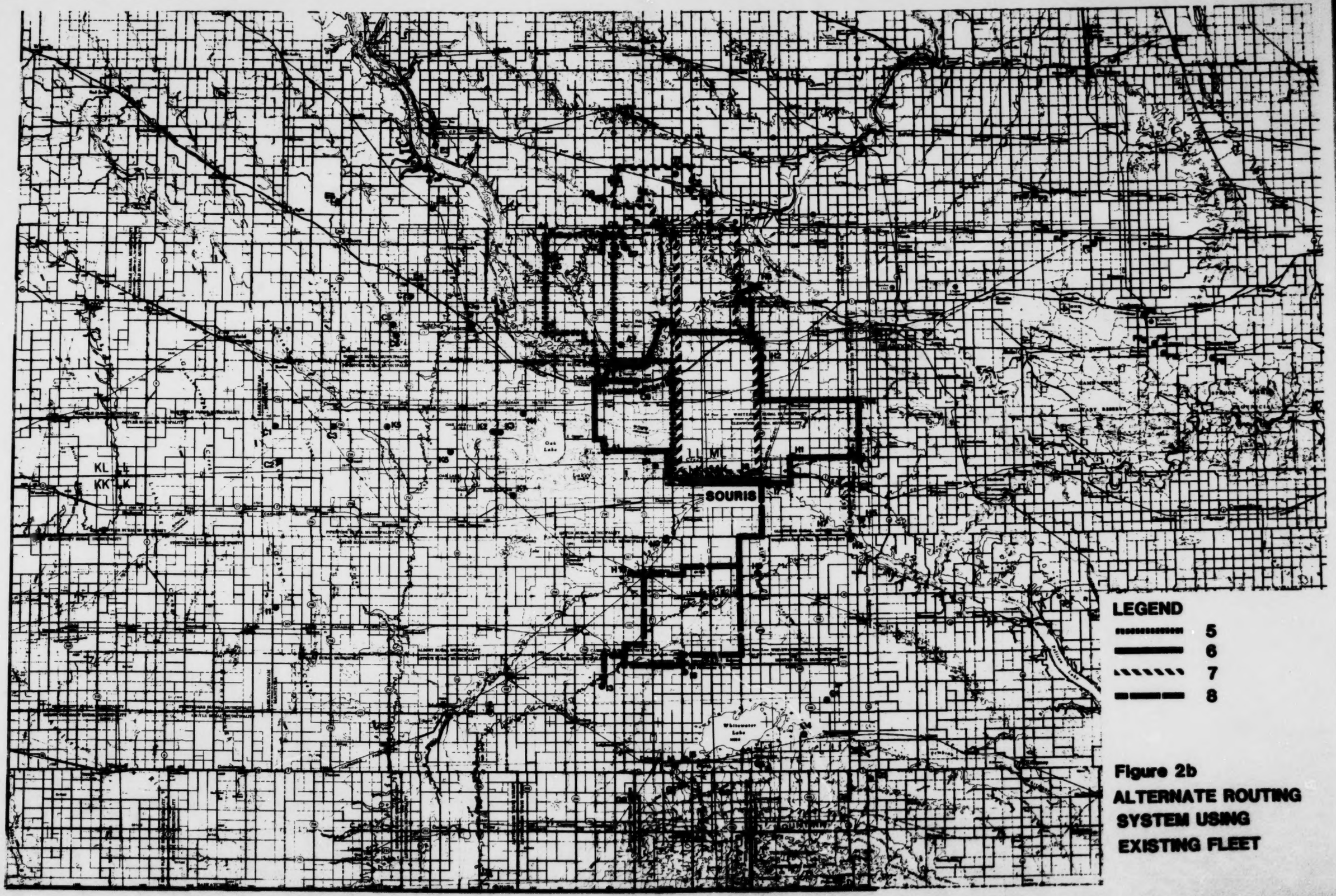

Figure 2b
ALTERNATE ROUTING SYSTEM USING EXISTING FLEET

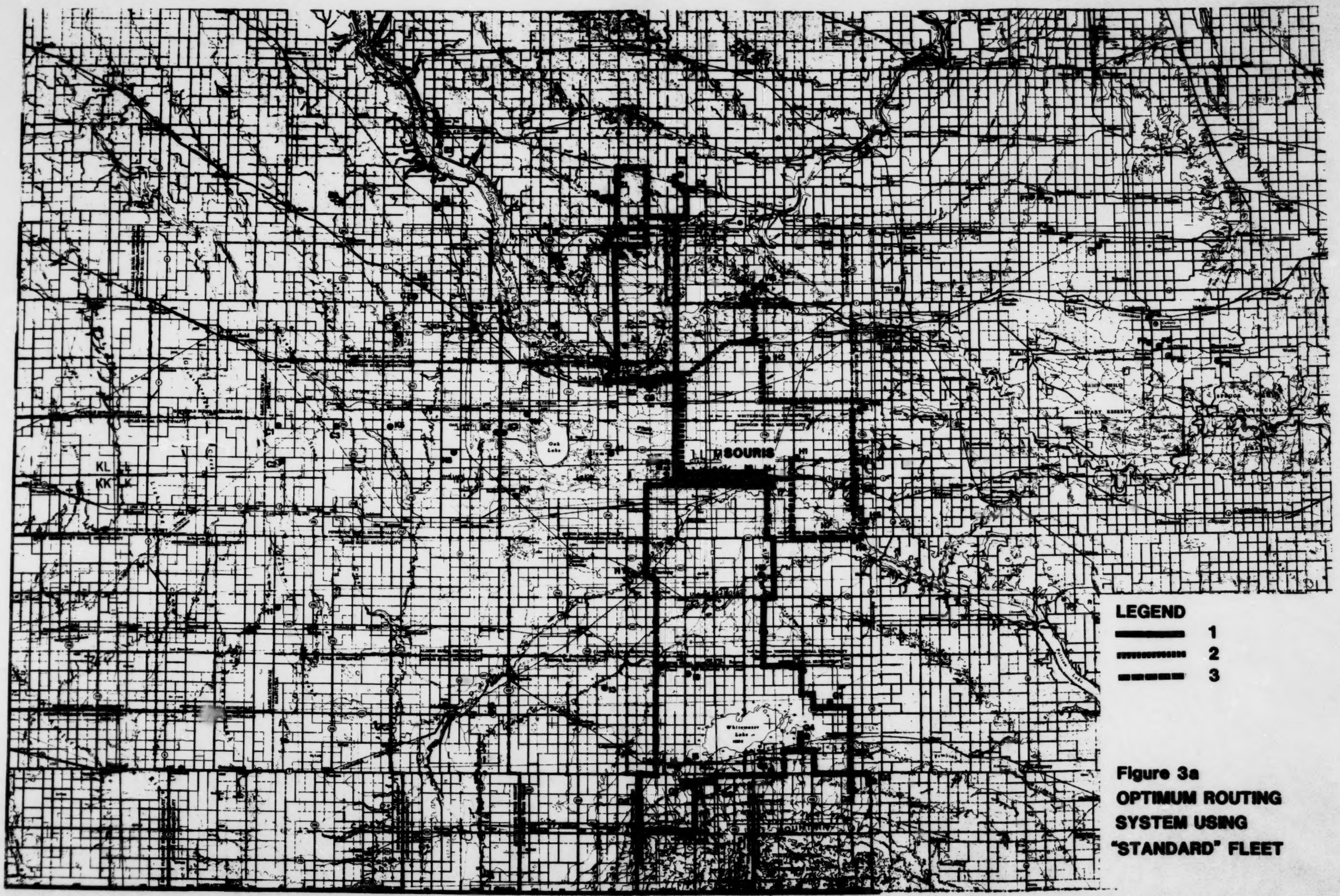

Figure 3a
OPTIMUM ROUTING SYSTEM USING "STANDARD" FLEET

Actual loads are higher in some cases than the rated capacity of the truck but in all cases are lower than actual recorded loads.

Table 3 gives the breakdown of distance travelled for each route. The totals for each segment are compared with the existing totals as measured by the Milk Markting Board in June, 1982. On a daily basis, the reduction in distance travelled in 482 km. On a monthly basis this amounts to 7,230 km, a reduction of 24.6 percent. The corresponding monthly fuel savings are estimated to be 3,675 litres.

A further analysis was carried out assuming all milk was carried in trucks of 11,392 litre capacity. It is used here to demonstrate the potential energy savings by using a fleet of such trucks. Successive route iterations were developed for the June average production figures (Appendix A). The loading histogram (Table 4) represents the optimum combination of maximum loading and minimum travel distance. Table 5 gives the breakdown of distance travelled in each route segment compared to existing distances. The optimum route configuration is shown in Figures 3A & 3B. For this optimized system, the number of routes can be reduced to seven. In order to minimize total travel distance, four of these routes would be based in Location B and three in Location A.

TABLE 3: REDUCTION IN SYSTEM DISTANCE TRAVELLED AND FUEL CONSUMPTION - EXISTING FLEET

Optimized Route	Distance Travelled (km)*			
	Empty	Pickup	Line-haul	Total
1	50	163	105	318
2	30	86	45	161
3	40	150	45	235
4	2	125	2	129
5	37	64	64	165
6	8	136	30	174
7	55	56	59	170
8	48	56	22	126
	270	836	372	1,478 x 15 = 22,170 km
Existing	485[1]	940	535	1,960 x 15 = 29,400 km
				Reduction 7,230 km
				Percentage Change 24.6%

Fuel saved-empty & line-haul - 378 km @ 2.1 km/l x 15 = 2,700 litres
Fuel saved-pickup 104 km @ 1.6 km/l x 15 = 975 litres
3,675 litres

Percentage Change 22.8%

* Note: This is "paid" distance travelled, ie., from the plant to the first collection point. Actual distance from home base to the first pickup (from odometer readings) is 548 km.

TABLE 2: LOADING HISTOGRAM - OPTIMUM ROUTE SYSTEM - EXISTING TRUCK FLEET

Optimum Route	Collection Points												Total (litres)	Rated Truck Capacity (litres)
	1	2	3	4	5	6	7	8	9	10	11	12		
1	I1 1,338	C2 893	C1 901	C3 547	C4 900	C5 1,302	C7 1,480	E6 365	E4 2,896	E2 817	E3 492	E5 1,468	13,299	13,290
2	K6 2,590	K5 1,346	C6 942	B4 1,278	B3 1,810	K4 1,381	K2 1,658	K3 1,229	K1 1,638				13,882	13,290
3	I1 1,004	I4 557	I5 1,564	G9 642	G8 1,493	G7 1,015	G6 619	G5 875	G4 424	G2 817	G3 1,099	G1 1,270	11,379	11,392
4	I8 1,398	B1 530	H9 3,124	H8 578	H7 2,020	H6 1,997	H5 653	I7 1,000					11,300	11,392
5	B2 904	A6 892	A5 323	A4 2,914	A3 448	D8 414	D7 1,042	D10 672					7,608	7,594
6	H1 999	H4 653	H2 524	H3 1,419	A2 1,885	C8 616	A1 1,388						7,594	7,594
7	D1 429	D4 826	D5 1,130	D6 678	D9 1,182	E1 1,480	D3 546	D2 685					6,956	7,594
8	I6 927	I3 911	H10 1,878										3,716	7,594
													75,834	

Note: 1. Average daily production figures for June 1982.
2. Alpha-numeric designations refer to existing route and collection point (see Appendix A).

TABLE 5: REDUCTION IN SYSTEM TRAVEL DISTANCE AND FUEL CONSUMPTION - HIGH-CAPACITY TRUCK FLEET

Optimized Route	Distance Travelled (km)*				
	Empty	Pickup	Line-haul	Total	
1	56	114	40	210	
2	19	180	3	202	
3	48	111	72	231	
4	42	144	3	189	
5	11	97	29	137	
6	50	108	69	227	
7	67	113	38	218	
	293	867	254	1,414 x 15 = 21,210 km	
Existing	485[1]	940	535	1,960 x 15 = 29,400 km	
				Reduction	8,190 km
				Percentage Change	24.9%

Fuel saved-empty & line-haul - 473 km @ 2.1 km/l x 15 = 3,379 litres
Fuel saved-pickup 73 km @ 1.6 km/l x 15 = 684 litres
4,063 litres

Percentage Change 25.2%

* Note: This is "paid" distance travelled, ie., from the plant to the first collection point. Actual distance from home base to the first pickup (from odometer readings) is 548 km.

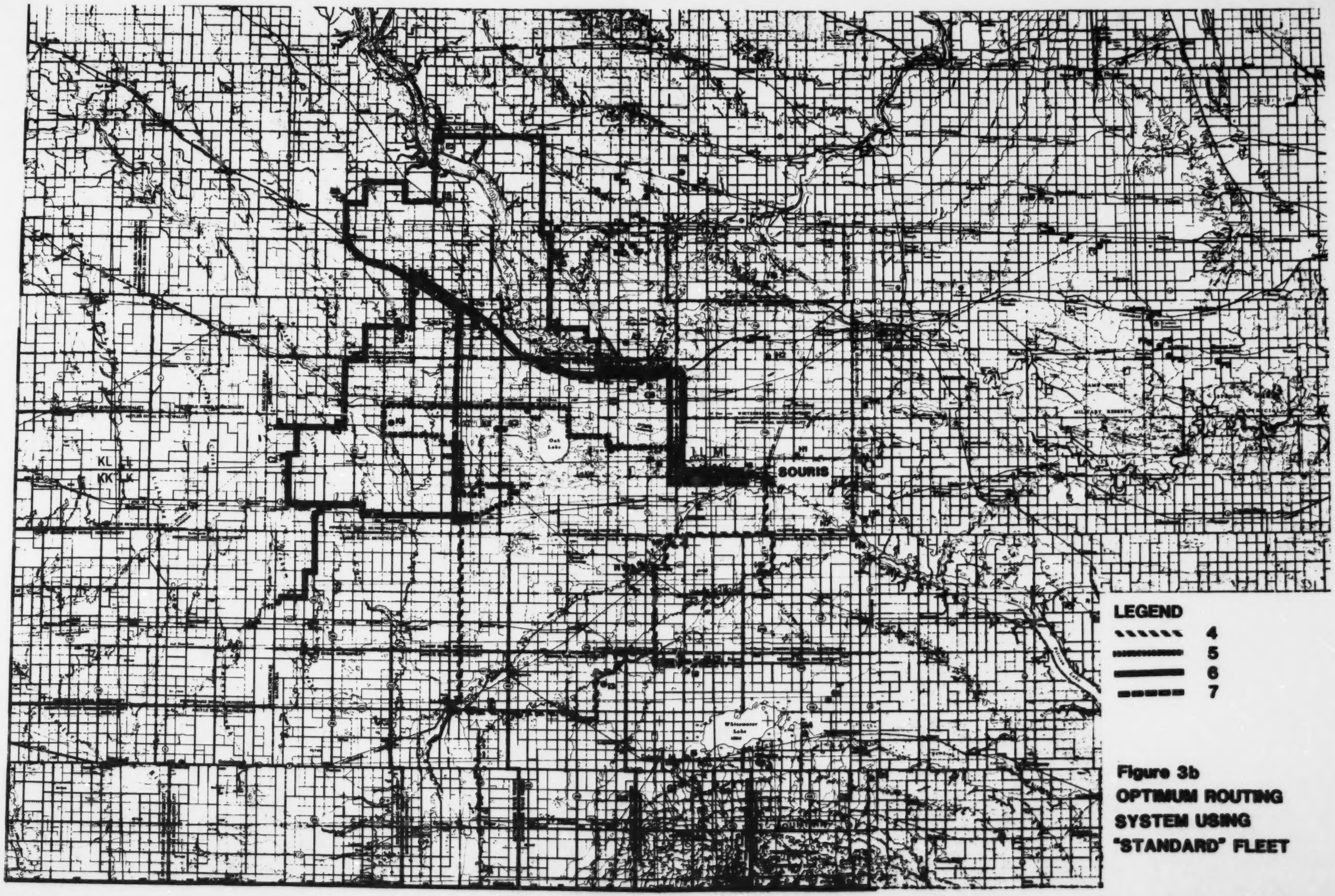

Figure 3b
OPTIMUM ROUTING SYSTEM USING "STANDARD" FLEET

On a daily basis, the reduction in distance travelled is 546 km. On a monthly basis, this amounts to 8,190 km, a reduction of 27.9 percent. The corresponding monthly fuel savings are estimated to be 4,063 litres.

The total production in December is much lower than for June. According to figures obtained from the Milk Marketing Board, some producers produce much lower volumes. While the carriers are able to combine segments of two routes in a single run, the actual reduction in distance travelled is insignificant since the basic loop routes are still covered. An analysis based on December production figures shows that, theoretically, the seven routes developed using high capacity trucks can be reduced to six. In practical terms, however, it is more effective for the carriers to maintain the basic route system and keep all trucks in service.

Thus, the theoretical results of the December analysis have not been considered to be realistic. It can be assumed that the fuel savings derived from the June analysis would remain relatively constant on a month to month basis.

The seven routes shown on Figure 3A & 3B all have overlapping or intersecting segments. Thus, in the event a truck is loaded to capacity before reaching the end of its run, or suffers a mechanical breakdown, another truck can be re-routed to complete the run with a minimum of time lost or extra travel distance incurred. Currently, such a system is in effect, and depends for communications on telephone calls from or to the producer's farms. A carrier with a problem can call the Milk Marketing Board office and staff there, knowing approximately where another carrier would be at the time, can call the next producer in line with a message.

5. CONCLUSIONS

Reductions in fuel consumption and operating cost can be effected in a number of ways. In the most extreme case (using high-capacity trucks and an optimized route system) a 27.9 percent reduction in actual distance travelled can be demonstrated in the peak month of June (Table 5).

Reductions in distance travelled and fuel consumption can be achieved as follows:

1. Route rationalization between plants. For example, if Route F were based in Brandon rather than Location A, an immediate reduction of 1,500 km a month and a reduction in payments of $262.50 per month can be realized. This may be offset by the possible addition of another route to the Location A plant. Because other route systems were not studied, the net effect is unknown. In addition, the cost to the operator would be reduced by removal of the round-trip distance between Location B and Location A (108 km). The total monthly reduction would be 3,120 km with a corresponding estimated reduction in fuel consumption of 1,485 litres.

2. Assigning routes on the basis of the home base of the carrier. If all the trucks in the study area were of equal capacity, which is not the case here, a potential reduction of 2,265 km monthly can be demonstrated by re-assigning Routes A, C, G and H to the carrier whose home base is geographically closer to the collection points. The corresponding reduction in fuel consumption is 1,080 litres.

3. Route optimization using the existing truck fleet. Table 3 shows an actual reduction of 7,230 km monthly or 24.6 percent of existing actual distance travelled. The estimated reduction in fuel consumption is 3,675 litres monthly.

4. Route optimization using a fleet of high-capacity trucks. Table 5 shows an actual reduction of 8,190 kms monthly or 27.9 percent of existing actual distance travelled. The estimated reduction in fuel consumption is 4,063 litres monthly.

The route optimization demonstration project carried out for the Manitoba Milk Producers Marketing Board revealed that using the

existing truck fleet, a potential reduction in distance travelled of 24.6 percent could be realized. Assuming that the 64 trucks operated by the 27 carriers travel an average of 62,000 km/year*, they would now travel 46,750 km/year saving slightly less than a half million litres of fuel per year (497,000 litres) if the 24.6 percent saving in travel distance and 22.8 percent saving in fuel consumption could be achieved universally.

At first glance, saving 25 percent in distance travelled would imply the possibility of eliminating 25 percent of the existing fleet - approximately 16 trucks. Fleet reductions could be achieved through attrition of aged fully depreciated equipment or by selling off surplus trucks. The ownership of a smaller fleet of trucks doing all of the required milk collection work would translate into significant capital/depreciation expenditure reductions for the Milk Marketing Board. It is more likely, however, that reducing the distance travelled by trucks serving Manitoba's milk plants will result not in the elimination of 16 trucks but rather, in decreases in the productive utilization of the existing fleet. For example, if two trucks are currently fully employed serving a given plant and through route optimization their travel distance is reduced by 25 percent, two trucks (and not 2 x .75 = 1.5 trucks) will still be required to serve the route.

It is therefore, apparent that the elimination - in significant amounts - of surplus capacity can only be readily achieved if the entire system/network can be subjected to route optimization techniques. Applying route optimization to entire fleets and networks represents the maximum possible travel distance and fuel savings attainable. By removing territorial boundaries on individual operators and transforming them into homogenous units of bulk milk

* Figure supplied by Milk Marketing Board.

transportation capacity, additional opportunities for reducing travel distance would become obvious. The principal constraint in attempting to apply route optimization in this manner, however, is that, to be effective, the ownership of the fleet would most likely have to be concentrated within the hands of one operator.

6. DEMONSTRATION PROJECT

The conclusions of the study can be implemented over a period of time. Since two of the suggested cost-saving measures evaluated in this study involve a conversion of tank sizes to a larger size, it is not likely that these can be implemented in the near future. However, the other measures require only a policy decision on the part of the Milk Marketing Board followed by negotiation with the affected carriers.

While the analysis was carried out on the collection system based in Souris, the findings and conclusions are applicable to all other collection systems in the province. In these other systems, there may be no constraints posed by differing sizes of tanks and trucks in operation. Thus, the conclusions of this study could be effected in a demonstration project in another area.

The following steps in the demonstration project are recommended:

6.1 Remove Route F

This route would be more economically served by a carrier based in the Brandon-Carberry area, serving one of the two milk plants located in Brandon. In order to balance the number of routes operated by each carrier, another route would have to be allocated to the current contractor with

the milk delivered to Location A. Ideally, this replacement route should have approximately the same number of producers and the same daily average volume of milk. The change-over could take place when contracts are next renewed.

Similar instances of route rationalization, and perhaps some more amenable to change, may be found throughout the system. It is recommended therefore, that staff of the Milk Marketing Board identify other routes which can be re-assigned and negotiate appropriate changes with the carriers. Thus, if it is found not be practical to re-assign Route F, other routes may be available.

6.2 Route Optimization - Existing Fleet

It has been shown that potential travel distance savings of up to 25 percent and fuel savings of up to 23 percent can be achieved by optimizing the route system and using the existing truck fleet.

Implementation of this measure should take place with the re-negotiation of new contracts. Prior to implementation, the recommended route structure (Table 2) should be reviewed by Milk Marketing Board staff, the producers and the carriers to ensure that there are no unforeseen difficulties. Once implemented, the first 12 months of operation should be carefully monitored with respect to costs, pick-up times, distance travelled and time taken to complete the routes.

A potential problem may be some producers' inability or unwillingness to conform to a new collection schedule. Where pick-up times are later this problem may not be severe, but where they are earlier there may be difficulty. This could result in additional distance travelled when a carrier must double back or detour to pick up from a producer who was not ready at the scheduled time. Frequent occurances could jeopardize the viability of the demonstration project. It is incumbent upon the Milk Marketing Board to ensure that producers can and do meet schedule pick-up times.

6.3 Route Exchange

Before proceeding to route optimization, it can be shown that an exchange of routes between carriers to reflect their geographic proximity to the producers can result in savings to the Milk Marketing Board and to the carrier. This exchange, however, can only take place if the trucks serving the routes in question are of similar capacity. This is not the case in this study.

Larger tanks could not be fitted to the existing trucks equipped with the 7,594 litre capacity tanks. Furthermore, the tanks have an economical life of about 10 years and cost approximately $20,000 to $25,000 to replace. Thus, unless the smaller tanks are close to the end of their economical life, there is no benefit in changing them and incidentally, changing to larger trucks to carry them.

The Milk Marketing Board does recognize the concept of a "standard" tank size in that operating payments are based on truck and tank unit size of 11,517 litres. Staff of the Milk Marketing Board have advised that the Board is not in a position to tell the carriers what size of truck and tank they should operate. However, there are obvious advantages to having a fleet of similar sized trucks and it would certainly be to the Board's economic benefit to use "persuasion" to convince carriers to convert to a standard size truck up to legal weight limits.

In the meantime, it is recommended that staff of the Milk Marketing Board search their files for instances of carriers with similar sized trucks operating on routes some distance removed from home base. An exchange of routes according to the principles outlined in this study would result in reduced costs and could be implemented with the negotiation of contract renewals. Again, the exchange should be monitored for 12 months.

6.4 Route Optimization - Standard Fleet

It can be demonstrated that the maximum benefit due to route optimization can be achieved when the entire fleet is converted to a single standard size. Again, since the carriers operate as independent haulers, the Board is not in a position to dictate tank size. However, the potential reduction (28 percent in travel distance and 25 percent in fuel consumption) certainly indicated that this approach should not be dismissed.

It is recommended that staff of the Milk Marketing Board analyze the existing province-wide fleet composition with the following objectives:

A. to determine the "optimum" tank size and corresponding truck size and fuel type (gasoline or diesel);

B. to determine how many existing tanks and trucks do not conform to the "optimum" size and type;

C. to determine the costs of a conversion program over, say, a 5-year period to standardize the fleet;

D. to compare these costs to a potential saving in fuel costs in the order of 25 percent overall.

APPENDIX A

EXISTING ROUTE STRUCTURE

APPENDIX A

EXISTING ROUTE STRUCTURE (June 1982)

Producer Number	Base	Route Location #	Travel Distance (km)		Load (litres) Peak	Load (litres) Average
18-972-7	Location A	A1	empty	31	1,566	1,388
98-144-6		A2			1,969	1,885
47-130-9		A3	pickup	75	525	448
30-912-5		A4			3,108	2,914
30-922-2		A5			337	323
42-955-2		A6	line-haul	68	972	892
				174		7,850
29-162-8	Location A	B1	empty	19	609	530
94-000-5		B2			945	904
83-063-6		B3	pickup	73	1,910	1,810
71-042-6		B4	line-haul	74	1,494	1,278
				166		4,522
93-098-9	Location A	C1	empty	92	962	901
90-844-5		C2			958	893
36-747-0		C3			570	547
63-642-9		C4	pickup	117	994	900
96-780-0		C5			1,537	1,302
24-632-7		C6			1,052	942
91-995-5		C7			1,595	1,480
43-080-3		C8	line-haul	40	677	616
				249		7,581

Appendix A (Continued)
Existing Route Structure (June 1982)

Producer Number	Base	Route Location #	Travel Distance (km)		Load (litres) Peak	Average
52-789-7	Location A	D1	empty	51	458	429
19-553-3		D2			715	685
43-060-9		D3			717	546
29-242-3		D4			915	826
65-322-4		D5	pickup	79	1,181	1,130
47-044-9		D6			776	678
32-979-4		D7			1,101	1,042
47-122-8		D8			429	414
97-515-1		D9			1,333	1,182
19-704-4		D10	line-haul	64	712	671
				194		7,603
52-202-5	Location A	E1	empty	76	1,540	1,480
41-130-1		E2			1,882	817
18-848-5		E3	pickup	81	592	492
67-085-4		E4			3,084	2,896
53-980-1		E5			1,575	1,468
56-953-8		E6	line-haul	107	704	365
				264		7,518
80-842-2	Location B	G1	empty	48	1,573	1,270
31-480-6		G2			897	817
41-680-1		G3			1,450	1,099
63-288-9		G4			472	424
34-270-0		G5	pickup	109	920	875
38-111-4		G6			7C6	619
19-699-8		G7			1,072	1,015
56-999-4		G8			1,540	1,493
93-301-2		G9	line-haul	74	717	642
				231		8,254

Appendix A (Continued)
Existing Route Structure (June 1982)

Producer Number	Base	Route Location #	Travel Distance (km)		Load (litres) Peak	Average
73-221-3	Location B	H1	empty	10	1,090	999
41-566-6		H2			590	524
26-992-2	"	H3			1,869	1,419
41-670-4		H4			848	763
19-097-8		H5	pickup	162	821	653
16-510-7		H6			2,258	1,997
44-230-9		H7			2,078	2,020
86-230-3		H8			716	578
10-866-9		H9			3,130	3,124
25-821-8		H10	line-haul	39	2,017	1,878
				211		13,955
30-020-5	Location B	I1	empty	108	1,427	1,338
93-242-4		I2			1,650	1,004
94-532-7		I3			1,002	911
22-172-4		I4	pickup	175	607	557
93-633-6		I5			1,722	1,564
42-450-5		I6			1,191	927
30-645-8		I7			1,122	1,000
30-782-9		I8	line-haul	3	1,493	1,398
				286		8,699
75-814-5	Location B	K1	empty	50	1,794	1,638
93-974-4		K2			1,710	1,658
62-742-5		K3	pickup	69	1,310	1,229
93-810-1		K4			1,531	1,381
73-905-4		K5			1,416	1,356
93-811-4		K6	line-haul	66	2,698	2,590
				185		9,852

APPENDIX B

ROUTE OPTIMIZATION TECHNIQUES

APPENDIX B

ROUTE OPTIMIZATION TECHNIQUES

For a collection or delivery system serving a large number of points on a relatively small network, computer programs have been developed which minimize the total length of the travel path or the total time required to cover the routes. Systems such as garbage collection or door-to-door postal delivery are typical of those analyzed in this fashion. The algorithms used are generally fairly simple, involving such directions as right turns only at intersections, capacity restraints and penalties for U-turns or double coverage.

In the case of a system involving relatively few points on a widely spread geographic network, computer programs are of dubious benefit. The effort required to describe and code the network is usually out of proportion to the advantages to be gained such as the ability to generate quickly a number of alternative routing systems.

The analysis of the route system serving the Cheese Plant in Location A is a case in point. The 77 producers are spread over a wide area of southwestern Manitoba and are currently organized in 10 basic collection routes. The geographical grouping of some of the producer locations are such that the routing system is, for all practical purposes, the best that can be achived. Other producers are located close enough to the plant that their allocation to any one of several routes would not make any significant difference in total distance travelled.

Thus, it was determined that the application of relatively sophisticated computer routines to this specific problem of route optimization was not warranted. Thius is not to say, however, that the principles underlying the application of these programs were not used. On the contrary, the principles were used and augmented by the application of experienced judgement. This latter factor cannot be built into a computer program but is invaluable in assessing choices available to drivers in making a series of collections or deliveries.

The technique used to optimize the routing system, while at first sight appearing simplistic and unsophisticated, in fact requires a good deal of knowledge of the operation of collection and delivery systems. Not only does each alternative route developed for analysis have to be measured for length and volume-capacity ratio, it has to be a realistic alternative in the first place. In other words, it would be a route that a driver of many years' experience would choose voluntarily, given that he had to make collections at certain designated points.

URBAN DISTRIBUTION SYSTEM

1. INTRODUCTION

The route optimization demonstration project described in this report was initiated under the Canada-Manitoba Conservation and Renewable Energy Demonstration Program. The intent of the project was to demonstrate the potential energy savings to be gained by route optimization techniques applied to rural distribution operations, urban distribution operations and a school bus system. This report deals with the urban system.

The rural distribution study is described in a separate report[1]. The study of the school bus system was not carried out.

The project was administered by the Transportation Programs Branch of the Manitoba Department of Highways and Transportation on behalf of the Manitoba Department of Energy and Mines and the Department of Energy, Mines and Resources Canada. A consultant was retained to carry out the project.

Selection of an urban distribution system was undertaken by the Transportation Programs Branch with input from the Consultants. The client is a warehouse/distribution operation supplying merchandise to a number of customers throughout Manitoba. Customers range in size and type from large bulk customers to small retail operations of various sizes.

1 Route Optimization Demonstration Project
Part 1: Rural Distribution System:
Manitoba Department of Energy and Mines,
May, 1983.

Within the city deliveries are normally handled with a fleet of 11 leased trucks, plus two company-owned tractor-trailers. In addition, five tractors and six trailers are used for out-of-town deliveries. The approximate average cost to the client of the leased fleet (including drivers) is $17 per hour per truck.

The purpose of the study was to determine an optimum routing system for deliveries within Winnipeg which would result in a significant decrease in total fleet travel distance.

For this purpose, trip sheets and load and signature sheets for a four-week period were obtained from the company. From them, a typical day was selected and an analysis of delivery patterns and routing carried out.

2. DEFINING THE CURRENT SYSTEM

Typically, orders are received at the order desk up to 5:00 p.m. for next day delivery. These orders can be received by telephone, by pre-printed form or, in the case of the larger customers, by computer link. The warehouse operates around the clock on a shift system. Orders received up to 5:00 p.m. closing time of the order desk are transmitted to the warehouse by 9:00 p.m.

Shipments for morning delivery are made up and loaded overnight so that trucks can depart at 7:00 a.m. The shipper is responsible for determining how many orders constitute a truck load. Generally a truck carrying two or more orders will make these deliveries in the same area of the city.

As trucks complete their routes and return to the warehouse they are dispatched again as required. The earlier second runs may still be carrying the orders made up the night before. The later runs tend to be in response to orders received that morning for same day delivery.

While the shipper makes every effort to utilize truck capacity to the maximum and to minimize long distances between deliveries, he generally has very little flexibility. Thus, trucks are dispatched in response to late orders, often with considerably less than full loads and often to destinations in widely separated parts of the city.

A particular factor which may cause delivery problems is the late arrival of incoming merchandise. In cases where orders are made up in anticipation of the arrival of such merchandise, its delay may necessitate a second special delivery to the customer.

To cope with small rush orders, the company operates a leased van (with driver) and occasionally employs a delivery service in an overload situation. In addition, 3 or 5-ton trucks are leased on an hourly basis for special deliveries which cannot be handled by the regular fleet.

The rationale behind this apparently cost-inefficient service is the need to establish and maintain a good customer base. It is felt that a perceived reduction in quality of service would lead to customers switching to other distributors. This has apparently happened and was a major factor in the client dropping a requirement for a $250 minimum order.

Some attempt has been made to pre-plan the delivery system. For example, one group of customers file one order per week for all their outlets. Unfortunately, there is no incentive for other customers to do this, and many customers have developed the habit of making daily orders for small amounts of merchandise. This is at least partly due to the fact that many of these customers have limited storage space. Within management, there has been discussion on the subject of imposing a minimum order size, but as noted earlier, the competitiveness of the market and the lack of conclusive date has precluded any attempt to implement such a proposal.

3. CRITERIA FOR OPTIMIZATION

The analysis of the client's operation began with the order system and followed through to the delivery points. Although route optimization as such does not include warehouse operations, the make-up of the orders and the organization of the loads on the dock are essential elements in ensuring the effective utilization of the trucks. Thus, the analysis included an examination of the current methods of filling the orders and making up the loads.

The major objective of the route optimization analysis was to ensure maximum pre-planning such that truck capacities are fully utilized and route distances minimized. This in turn required that cut-off times for orders be examined and that alternative methods of dealing with small rush orders be investigated. Such options as minimum order quantities, pre-planning orders, alternative delivery methods and the use of cost incentives and surcharges were considered.

In terms of the route structure, the major criteria were the maximum utilization of truck capacities, the minimization of travel distances and the avoidance of traffic congestion in peak periods. The geographic proximity of delivery points was considered to be important in pre-planning routes and this in turn led to the concept of defining delivery zones in the city.

4. ANALYSIS

4.1 Existing Routing

Driver's trip sheets and load and signature sheets for October, 1982 were analyzed. Wednesday, October 6 was selected as being typical of a delivery day without undue pressure on loading dock staff.

It was reasoned that if savings in operating mileage could be demonstrated for a relatively light day, where time permitted some orderly planning, then the potential existed for greater savings on peak days. There was an average of 7.4 deliveries per regular fleet that day, with a daily average of 8.1 for the week and a peak of 9.4 on the Friday, normally the busiest day.

There was some difficulty in correlating the trip sheets and the load and signature sheets. The drivers of the van and of special vehicles hired on an hourly basis to deal with overload situations do not fill in trip sheets. Some load and signature sheets appeared to be missing and in many instances there were discrepancies between the two sheets in the number of cases delivered to a particular customer. Despite these problems, however, the base data were considered complete enough to develop a reasonably accurate record of the day's activities. The discrepancies were not considered to be significant enough to alter the conclusions.

Individual truck routes were plotted on overlays on a map of the city. Delivery points were located and the most direct routes between the warehouse and the delivery points were selected. Route lengths were calculated from the overlays and were checked by actually driving the routes.

The number of routes (or trucks) serving a given area and also the geographic spread of delivery points loaded on a single truck were deterined from the route plots. It was immediately obvious from the plots that as many as five trucks were in one particular area of the city at some time during the day. Some delivery routes, particular those later in the day, covered long distances for only a few deliveries.

On the particular day studied, three tractor-trailers, nine straight trucks, a van and five specials were utilized for deliveries within the city limits. All vehicles except for the specials are part of the leased fleet, while specials are trucks hired on an hourly basis to accommodate overload situations.

Many variables exist in the make-up of truck loads. These include the charateristics of the customer, the mix of his order, the size of the order, variable packaging, overall volume and overall weights. A sampling of truck loads and orders was assessed. A relationship between overall truck load volume and weight appears to exist (i.e. a truck 50% full carries approximately 50% of allowable load by weight).

Other variables such as customer characteristics or total volume of orders were not measured in the context of this study. For analysis purposes truck utilization was defined as the ratio of the estimated weight of the load to the weight capacity of the truck.

A utilization analysis was made of truck movements in the morning and afternoon and for single deliveries all day. Single deliveries were runs made with only one delivery point, typically to bulk customers. Special trips were not included since truck capacities were unknown. The total return travel distance from the warehouse was identified for each trip as was the incremental distance from stop to stop. The additional travel distance required to make a pick-up was also calculated.

In the morning, where some degree of pre-planning is available, approximately 67% of total available truck weight capacity was used. Utilization dropped to 36% for the afternoon runs. The utilization of trucks on single deliveries to bulk customers

varied widely, but averaged 47%. Overall, the average utilization for the day was 40%, indicating that only about half the total available truck capacity was used.

The inference could be drawn that, theoretically, the same deliveries could be made with half the number of trucks actually being used. In practical terms, however, this is not possible. It is more efficient, for example, for the client to run a tractor-trailer loaded to half its capacity on a single bulk customer delivery than to fill up the available space on the same truck with a number of smaller deliveries.

Even where a load is made up from a number of small deliveries, a number of factors come into play which make it impractical to try to achieve 100% load utilization. These include constraints on pallet stacking, constraints on combining different types of deliveries on one pallet, and the statistical impossibility of making up a full load each time from random sized orders. For the purposes of this analysis, 85% utilization was taken as a practical limit.

The pick-ups made during the day from other warehouses or suppliers were analyzed. These pick-ups are listed only on drivers' trip sheets and thus the number of cases picked up are estimates only. Three of the six pick-ups were made on trips which also involved deliveries, while the other three were made specifically for that purpose.

Occasions where deliveries were made twice or more during the day to a single customer were flagged. In most cases one delivery took place in the morning and one in the afternoon. This suggests that the later deliveries were make-up orders or

that part of a later scheduled delivery was rushed. However, in two cases, the time of arrival logged on the trip sheets suggest that two trucks were there at the same time.

The relationship between time of order and time of delivery was investigated. There was no major difficulty with previous day orders which are currently made up overnight These could be assigned to trucks and delivery routes in a relatively straight forward fashion. The difficulty occured with same day delivery orders. In order to handle these effectively, the concept of cut-off delivery times in conjunction with a zonal delivery system was investigated. Essentially, this concept involves designating one or more trucks (and loading docks) for a particular city zone and then loading only deliveries for that zone on the designated truck.

4.2 Optimized Routing

An examination of the existing routings reveals five distinct types of operation. They are:

1. Single delivery runs primarily to bulk customers;
2. Morning deliveries;
3. Afternoon deliveries;
4. Specials;
5. Pick-ups.

Morning and afternoon deliveries were analyzed separately. It was assumed that a delivery made in the afternoon could not be brought forward in time and morning deliveries could not be delayed except in special circumstances. Single delivery runs, specials and pick-ups were all, with the exceptions noted earlier, single trips with one delivery or one pick-up per

trip. These were examined to determine where they might be combined with other deliveries or, in the case of the specials, where the load could be carried on a truck from the regular fleet.

Three of the pick-ups were already made in combination with delivery trips and these were not altered. The other three were allocated to return trips being made by trucks after finishing deliveries in a nearby area of the city at approximately the time the pick-ups could be given to the drivers before leaving the warehouse or by phone-in before completing deliveries.

Alternative routes were plotted on overlays and analyzed to determine the best combination of distance and truck utilization Delivery sequences were examined to ensure that delivery times and truck start and finish times were approximately the same as before.

Trips for the morning and afternoon deliveries were developed on the basiis of a zonal system in order to minimize total travel distance. The implications and implementation of a zonal system are discussed in Section 5.3 of this report.

The distances covered on each trip are of the same order as the existing routings. The longest run, 89.6 km, involving a rural delivery, compares with the longest trip of 75.0 km on the existing route, also involving the same destination area.

Nineteen deliveries are included in the optimized route, but in terms of truck scheduling, that particular truck has been allocated only one other trip, a single afternoon delivery.

Start and finish times for each optimized run were estimated on the basis of the actual trips and care was taken to ensure that sufficient time was available for the deliveries and for loading. Typically, morning trips would begin at 7:00 a.m. or 8:00 a.m. depending on the accessibility of the first customers, while afternoon trips would begin at 2:00 p.m. and be completed by 4:00 p.m. or 5:00 p.m.

The re-allocation of loads to achieve higher utilization shows that, potentially two trucks could have been kept free all day. No deliveries were scheduled for the van in the morning, leaving it free to carry any excess over another truck's capacity on a supplementary run if required. Alternatively, another truck, which has a smaller capacity than the others, could have been used for this purpose.

Similarly, the analysis demonstrates that the five special trucks were not required. The loads allocated to these trucks were assigned to trucks in the regular fleet on completion of their deliveries.

If these results are representative of normal operation, the implication is clear. Two trucks out of the total fleet of 13 regular vehicles in use that day were not required nor were the specials. This would have resulted in a significant capital and operating cost saving to the client.

The utilization factors for morning, afternoon and single delivery trips were calculated. The morning utilization achieved is close to the practical limit of 0.85 while the afternoon is somewhat lower, reflecting the more widely scattered deliveries and the need to compromise between reducing travel distance and increasing utilization.

Since very litte adjustment was made to the single deliveries, the utilization rate here has increased only slightly. An examination of the trips showed that three deliveries made by semi-trailer units could have been made with 5-ton trucks.

The reductions in travel distance achieved through optimized routing will be summarized. The largest reduction, 95.4 km, occurs on the morning delivery primarily through increasing the overall utilization of truck capacity. The reduction for the afternoon deliveries is based on the combined travel distance of the existing afternoon and special deliveries. Overall, a total reduction of 197 km or 25% is demonstrated.

4.3 Delivery Zones

With the restructuring of the order system, the shipping dock would have the tools necessary to begin optimizing routes. The key to this process is the establishment of predetermined delivery zones in the city with a single truck making all deliveries)except large single orders) within that zone. Currently, an effort is made to use a zone system and this is particularly evident in the morning runs where some preplanning time is available. We suggest the concept of the zone delivery system be strengthened and used at all times to minimize total travel distance.

In this study, there has been no attempt to define zone boundaries precisely. It would be misleading to do so on the basis of an analysis of one day's deliveries, even if that day were reasonably representative. Also, since the number and size of deliveries to any one area of the city varies from day to day, flexibility in assigning loads is important. Thus delivery

points close to an assumed zone boundary could be serviced from one zone on one day and from the other zone on another day depending on the capacity utilization of the respective trucks.

Zone boundaries could be established on the basis of natural and man-made barriers such as rivers and railway lines. Traffic congestion delays tend to occur where there are a limited number of major road crossings of these barriers. However, other factors, such as the number of customers in a given area of the city and the ability of the road network to provide direct routes between delivery points, come into play.

As the basis for the route optimization in this study, six zones were considered. In developing optimized routes for this particular day, it was found that the six zones could be covered by five runs in the morning and four in the afternoon (plus single deliveries). This may not necessarily be the case for other days, hence the need for flexibility and continouus experience with the system before defining specific boundaries.

To integrate the zone delivery system with the order system, it is suggested that each customer number, shown on the computer generated order picking form, have suffixed to it a numeric digit representing the zone in which the customer is located. This would allow specific shipping doors to be designated for specific zones. The person filling the order would place the order in the correct door staging area. From this point, the efficiency of the system would depend on the shipper's knowledge of the city. He would arrange for the truck to be loaded in the reverse order of the route, i.e., last out - first in.

4.4 Cut-Off Times

Without cut-off times, orders can be received and delivery expected up to closing time for the office. This makes any attempt to plan effectively very difficult. Most of the first run morning routes show a relatively good effort to plan However, as the day progresses, the effects of other pressures become obvious. Routes overlap and many customers receive duplicate service.

Obviously, if one area (or customer) receives deliveries four times in one day, the client's trucks must arrive there within two hours of each other at most. In fact, it would not be surprising to find two trucks at one location at one time, as was observed in two instances.

An analysis of the relationship between orders and deliveries indicated that the process of preplanning and organizing loads could be made easier if certain cut-off times were established with related assured delivery times.

For example, all orders received in the warehouse prior to 9:00 p.m. on day one could be shipped on the first set of trucks on day two; all orders received between 7:00 a.m. and 11:00 a.m. on day two for delivery on day two, could, if possible, be shipped at 2:00 p.m. for same day delivery. Any rush orders received after 11:00 a.m. and before 3:00 p.m. on day two for same day delivery could be shipped via an outside service on a collect basis, or with a handling charge. Any orders received after 3:00 p.m. would not be delivered until the first trucks on day

three. Therefore, three order periods would be established as follows:

Period 1: 7:00 a.m. to 11:00 a.m. - same day

Period 2: 11:00 a.m. to 3:00 p.m. - same day - freight added

Period 3: 3:00 p.m. to 9:00 p.m. - next day

By arranging to have a local express, courier or similar carrier stop everyday at the warehouse, and by guaranteeing the contract carrier a minimum average number of deliveries every day over a year, the client should be able to negotiate reasonable delivery charges.

These delivery charges will undoubtedly be less costly than running the client's trucks to deliver the rush shipments and they would also discourage rush shipments and encourage planning on the part of the customers. The decision to implement cut-off times would be a matter of corporate policy and would need to be weighed against the possible loss of customers.

4.5 Minimum Order Size

Eleven deliveries made during the day consisted of five packages or less. Two trips were made (by the van and a special truck) for deliveries of 18 cases and 9 cases. The costs to the client for additional travel distance and travelling time would, in these instances, represent a major proportion of revenue received from the sale.

These costs could be reduced by establishing a minimum order size for all clients. This minimum order may be a dollar value based upon the nature of the client's business or a size or

quantity minumum. Less than minimum orders would be considered rush, regardless of the time the order is received and therefore subject to a handling charge of 'Freight Added' condition.

4.6 Pre-Planned Order Days

Currently, only one group of customers submit preplanned orders. One order is placed weekly for all customers in the city and deliveries are scheduled over the week. This permits easier scheduling of trucks by size and by routing. Other customers with similar types of operations should be encouraged to pre-plan as much as possible. This encouragement could take the form of a cash discount or guaranteed delivery time.

4.7 Truck Load Assembly

Since there is no uniformity in package size, it is difficult to pre-plan a route until an order is filled and assembled on the loading dock. Typically, loads are estimated in terms of number of pallets, with each pallet being able to accomodate a certain number of cases. Information on weights by product is stored in the client's main computer. Thus it would be a relatively simple matter for the computer to add weight measures, enabling a shipper to build truck loads more quickly and accurately.

This could be done by installing an on-line computer terminal on the loading dock. With direct access to the main computer, the shipper could quickly determine the weight of a single order or group or orders. The addition of a small printer to the terminal could enable the load and signature sheets, or at least a check sheet, to be produced automatically.

5. CONCLUSIONS

5.1 Travel Distance and Fuel Reductions

A total of 197 km of truck travel, representing 25% of existing travel, can be reduced by increasing truck utilization and optimizing routes. Taking a 5-ton truck as being representative of the fleet, and assuming a fuel consumption rate of 2.2 km/litre (45 litres/100 km), this results in a reduction in daily fuel consumption of 89 litres. Over a year, this reduction would amount to approximately 22,250 litres per truck.

5.2 Operating Cost Reductions

Reductions in fuel costs and operating costs would not accrue directly to the client, since the truck fleet is leased at an average rate of $17/hour, including driver. The major impact due to route optimization would arise from reductions in truck leasing costs. Since the analysis shows that two trucks would not be required, an estimate of potential cost reductions to the client can be derived by taking the daily lease cost of each truck (assuming an 8-hour day) and pro-rating that to an annual basis. Thus, the annual cost reduction to the client would be $68,000.

In addition, since no special hourly-leased trucks would be required, a further cost reduction would be effected. Assuming each special is required for three hours, the daily cost of five specials (at $17/hour) would be $255. On an anuual basis, this amounts to a futher savings of $63,750. The October monthly bill for hourly-leased trucks was $10,000, considered to be about average for the year. Thus, if all special hourly-leased trucks were eliminated, the potential annual savings would

amount to approximately $120,000. Because of the peak delivery demand typically experienced on Mondays and Fridays, it is unlikely that all use of special trucks could be done away with.

However, if the earlier conclusions with respect to pre-planning of orders and pass-through of rush delivery surcharges are followed up, most of the potential cost reduction could be realized.

5.3 Delivery Zones

The concept of grouping deliveries by zone should be strengthened. Zone codes could be added to order/packing forms and loading dock doors dedicated to specific zones.

5.4 Ordering Procedures

Maximum benefit can be obtained from pre-planning and greater truck utilization by implementing the following changes in ordering procedures:

1. Establish order cut-off times at the loading dock:
   - 11:00 a.m. - for same day delivery
   - 3:00 p.m. - for same day delivery with freight added charge
   - 9:00 p.m. - for next day delivery.
2. Establish minimum order size;
3. Encourage customer pre-planning of order.

5.5 Truck Load Assembly

More effective utilization of available truck capacity can be achieved by providing the means for loading dock staff to simulate loads prior to assembly. This could be done by installation of an intelligent computer terminal on the loading dock with the ability to print out weight and cube dimensions of individual orders.

6. DEMONSTRATION PROJECT

The analysis of the client's operation was carried out on the basis of a single day's activities. Although this day was selected as being typical of normal operations, the implementation of capital expenditures or reductions in the truck fleet should not be undertaken until the conclusions can be confirmed. This can best be achieved by reviewing operations over a period of time, say three months, and comparing such parameters as number of deliveries, total weight of deliveries and number of trucks used (including specials).

As noted earlier, the key to achieving maximum truck utilization is a more efficient loading dock operation. A major step in this regard would be the installation on the loading dock of a terminal linked to the main computer. A set of simple programs would enable the shipper to simulate loads on the computer screen and allocate trucks before the actual process of assembling loads begin. We recommend that immediate steps be taken to implement this installation.

In addition, other measures can be implemented quickly. These are:

1. Cut-off times for orders;
2. Minimum order requirements;
3. Pre-planned orders;
4. Dedication of loading dock doors to delivery zones.

The first three measures would require the consent and cooperation of sales staff, since they directly affect customer relations.

The fourth measure can be implemented on the loading dock immediately. It would require confirmation of the zones to be used, based on the longer-term review of operations. Once implemented, however, it would result in a much higher level of pre-planning for afternoon deliveries.

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